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Device Service Networks Maintenance Based on Components Migration in the Internet of Things

Jianhua Liu[a*],Weiqin Tong[a]

[a]School of Computer Science and Engineering, Shanghai University, Shanghai 200072, China

Abstract

Aiming at the failure of components problem in device service networks of internet of things, reliability of components was analyzed theoretically. Component-based migration maintenance strategy was proposed which analyzed link probability and degree of components migration, a components migration three-tier framework based on CM-ECA rule was proposed according to the process of dynamic migration of components which includes components migration in layer, components migration path layer, components migration out layer. The role of the CM-ECA rules in those three-tiered makes components migration and replacement time meet the deadline time for service completion, components migration path layer uses game-theoretic selection scheme. The experiments results show that the migration maintenance strategy make migration load tradeoff and components to be migrated and replaced within the deadline time.

Keywords:Internet of things;device service networks;component migration;game selection

1. Introduction

With the improvement of the wireless network infrastructure, internet of things (IOT) devices change from the simple modules to more powerful devices, these changes not only in its size, such as widescreen of mobile phones, tablet computers, but also device of software system changes from a single functional to smart phone operating systems, the number of procedures and modules dramatically increases. Furthermore, the hardware changes from single CPU device to the multiple CPU devices, a lot of devices

* Corresponding author. Tel.: +86-137-6439-6346.
E-mail address: ljh_541@163.com.

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are to be deployed in dynamic, self-organization and mixed network environment, many user's applications interact frequently between components and devices. However, although there are a lot of hardware changes, mobile systems due to the limited memory, CPU processing power, and other factors, result in the contradiction between a large mobile operating systems and resource-constrained mobile devices, it makes its software not the same as PC at any time ensure reliable operation. To balance this contradiction, the researchers proposed a variety of ways to avoid the occurrence of instability, such as, a platform independent security architecture was presented in multi-core system for mobile devices, smart phone, media player terminal, and low-power devices are added the system of energy management module to achieve the system robustness protection(Ashkenazi and Akselrod 2007). In addition, a number of adaptive technologies also produced, such as component migration technology(Fuggetta et al. 1998; Cai et al. 2001; Yu and You 2002), component replacement(Yu et al. 2001; Liu et al. 2010; Appavoo et al. 2003) and so on.

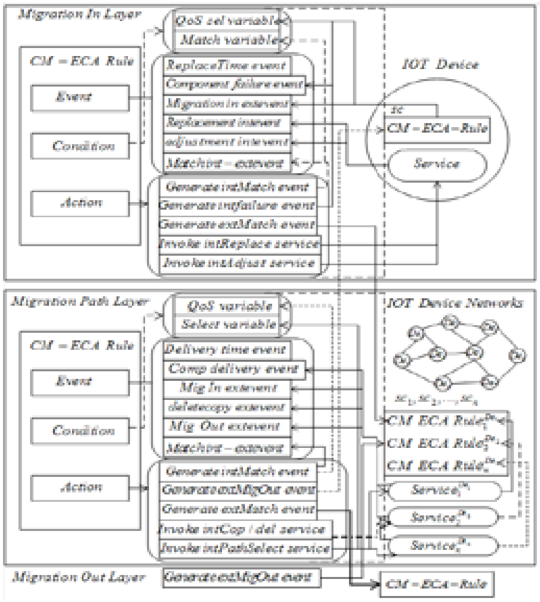

Fig.1. Component migration framework based on CM-ECA rule

This paper presents a component-based migration service maintenance strategy, which includes three dynamic processes, the component migration in layer, component migration path layer, the component migration out layer. The role of the CM-ECA rules on this three layers(Fig.1) makes the components complete the migration and replace within the deadline. CM-ECA rules contain a variety of conditions and actions variables and events services. Service coordinator(*sc*) delivers the message by using the event to connect the layers into a unified whole, determines the migration conditions and selection function to obtain values, such as the degree of migration and the probability of links.

2. Component migration framework based on CM-ECA rules

2.1. Migration in layer

The CM-ECA rules(Jung et al. 2007) are registered in the IOT devices. The event of component failure or QoS over the threshold makes the device generate a component failure to report the event management.

The events include the internal components matching, component replacement and service network adjustment event. The degree of migration is defined as:

Definition 1 The degree of service components migration in.

$QoS_d = \frac{R_i^U - used\ resource}{R_i^T - allocated\ resource} > \rho$, QoS_d is the threshold value of components migration and condition.

$M_u^{v,in}(t) = \frac{I_S^{v\leftrightarrow u}}{I_T^{v\leftrightarrow u}} + QoS_m$, $I_T^{v\leftrightarrow u}$ is the total number of interactions before time T between C_u and C_v . $I_S^{v\leftrightarrow u}$ is the total number of successful interactions before time T between C_u and $C_v \cdot QoS_m$ is the degree of QoS satisfaction between C_u and C_v .

Definiton 2 The degree of migration of service component migrating multiple service networks

It is represented as: $C_u \to \Omega(De_i(SN_k^j), De_{i+1}(SN_k^{j+1}),...,De_{i+n}(SN_k^{j+n}))$. $\Omega(x)$ is migration function.

$M_{\Omega(x)}^{C_u}(t) = \frac{\sum_{v=1}^{k} M_u^{v,in}(t)}{k}$,where $M_{\Omega(x)}^{C_u}(t)$ is average degree of migration of $C_u \to \Omega(x)$.

Definition 3 The migration of many-to-one.

$C = \{c_1,...,c_n\}$, $C_u \in C$, $C_{us} = \{C_{u1}, C_{u2},...,C_{un}\}$, $De_i(SN_k^j) \in SN$,where C is component, De is device. The set of C_{us} migrates to $De_i(SN_k^j) \in SN$, which is represented as: $C_{us} \to \Omega(De_i(SN_k^j))$ .Let $R(C^u_{De_i(SN_k^j) \to De_j(SN_k^j)})$ denotes C_i^u obtains QoS resource migrating from $De_i(SN_k^j)$ to $De_j(SN_k^j)$,so $R(C^u_{De_i(SN_k^j) \to De_j(SN_k^j)})$ is

$$R(C^u_{De_i(SN_k^j) \to De_j(SN_k^j)}) = \begin{cases} Cof(De_j(SN_k^j(C_i^u)) & if\ Cof(De_j(SN_k^j(C_i^u)) - Cof(De_i(SN_k^j(C_i^u)) > 0 \\ 0 & if\ Cof(De_j(SN_k^j(C_i^u)) - Cof(De_i(SN_k^j(C_i^u)) \le 0 \end{cases} \tag{1}$$

where *Cof* denotes QoS resource configuration function.

2.2. Migration path layer

When the *extMatch event* generates external matching event, the device component migration path selection layer receives this event, then sends it to event management to find matching components, and then judge by the matching variables, if there is no matching components, then it determines whether the time variable of matching the component event is more than deadline, if $t_m > t_{deadline}$, the failure of the match. The CM-ECA rules in migration path selection layers are mainly responsible for the selecting and matching components. Condition variables include QoS matching variables, path selection variables and time variables. Actions include internal actions (remove/copy service components).

Definition 4 Degree of path selection: $PathSel(t) = H_i^{v\leftrightarrow u} + QoS_{De} + D(Con_{vi\leftrightarrow uj}) + P_m$, $H_i^{v\leftrightarrow u}$ is hop number between C_u and C_v . QoS_{De} is use of resource between De_u and De_v . $D(Con_{vi\leftrightarrow uj})$ is the degree of link between devices. P_m is successful probability of replacement.

Definition 5 Migration risk: $Prob(x_i \ge t) = e^{-\lambda t}, t > 0$, the maximum migration successful probability is: $\ln P_m = \ln Prob(X_i \ge C_t^u) = \ln Prob(x_i \ge C_t^u - y_i) = \ln e^{-\lambda Max\{Max\{C_t^u - y_i, 0\}\}} = -\lambda Max\{Max\{C_t^u - y_i, 0\}\} = -\lambda P_{sf}$, X_i is total time of component replacement, y_i is a component replacement time. x_i is random variable followed exponential distribution. C_t^u is time variable of component replacement, n is the number of component. P_{sf} is failure probability, that is $Max(\sum_{i=1}^{n} P_m^i) = Min(\sum_{i=1}^{n} P_{sf}^i)$.

Definition 6 Link probability : it is a measure of the distance between devices that influences on different device type links. Link probability can be derived as:

$$P_{co}(z) = \begin{cases} P_{co}^{1}(z)=1, if\ 0 \le z < r_s \\ P_{co}^{2}(z)=1-(1-p)e^{-\lambda r_s}, if\ r_s \le z < r_m \\ H_i^{v \leftrightarrow u} \cdot P_{co}^{3}(z), if\ z \ge r_m \end{cases} \tag{2}$$

where $P_{co}^{3}(z)=P_{co}(r_m)(1+\varphi(r_m))$ (Cavalcanti et al. 2005),the minimum communication radius r_s ,maximum is r_m, service component migration process meets the minimum risk of failure $Min(\sum_{i=1}^{n} P_{sf}^{j})$ and maximum QoS requirements, which is represented as $M^{(C^u, De^v)}(P_{sf}, QoS) = Min(\sum_{i=1}^{n} P_{sf}^{j}) \cup Max\{QoS(C^u) - \rho, 0\}$. Migration path selection function is represented as: $M(C_{ij})=\delta \cdot M_j^N + H_{ij}$, M_j^N is the number of component to be migrated in device *j*. δ is constant. H_{ij} is hop number from failure device to matching service components. If $x_k \cdot t_k < x_j \cdot t_j < T_{ij}^{cd}$ and $\frac{H_{i \to k}}{v} < \frac{H_{i \to j}}{v} < T_{qu}$, components in device *i* have to change their selections to select new equipment *k* to migrate. $T_{ij}^{cd} = T_{qu}/H_e$ is the time of transmission component between devices, $x_k \cdot t_k$ is time of migrating in device *k*, T_{qu} is average deadline time. H_e is average hop number. $x_j \cdot t_j$ is the time of migrating in device *j*, x_k and x_j are the frequency of migrating. Nash equilibrium conditions can be derived as:

$$\delta \cdot x_j^f + H_{i \to j \to \ldots \to s} \le \delta \cdot (x_k^f + 1) + H_{i \to k \to \ldots \to s} \tag{3}$$

$$H_{i \to j \to \ldots \to s} = v \cdot t_j, H_{i \to k \to \ldots \to s} = v \cdot t_k \tag{4}$$

where *v* is rate of component transmission between devices. From Eqs. (3) and (4), we get

$$x_j^f - x_k^f \le \frac{\lambda_k v}{\delta}(t_k - t_j) + 1 \tag{5}$$

where λ_k offsets transmission delay. From Eqs. (5), we can derive that equilibrium condition relates with the rate of wireless network v ,components migration time t_j of selecting device *j*, and migration time t_k of selecting device *k*.

2.3. Migration out layer

When the CM-ECA rules in migration out layer are mainly responsible for the components to migrate out devices in time. *sc* generates *extMigOut* event (Fig.1)and sends event messages to the service component migration path selection layer devices for path selection. The *extMatch* event generates external matching event,the device in component migration path selection layer receives this event and decides action according to migration time of condition variable t_m , if $t_m < t_{deadline}$, component migration has not over deadline time.So, *sc* finds appropriate components to match failure components,then the components migrate out migration out layer. When device node generates *extMigOut* event to migration in layer, the CM-ECA rule management calls the component of replacement and chain adjustment services. The degrees of migration out is: $M_u^{v,out}(t)=QoS_m+F(v,u)$, $F(v,u)$ denotes function matching between components.

3. Experiment analysis

3.1. Maintenance method of performance analysis

The performance analysis mainly include two aspects: (1) Component migration method is an optional method, when appropriate components and one-hop link can not be found in device service networks, the component migration method is used to maintain IOT device service networks. As the number of the components migration increases, the greater δ value, the more number of migration actions. Experiment demonstrates the effect of the value of δ changing on the number of components migration. (2)The cost of service components to be migrated increases along with the number of devices to be selected and the number of hops from failure component to source component devices. Therefore, the experiment verifies the effect of migration in/out on each component migration time.

3.2. Performance Metrics

(1)In the case of the value of δ changing, experiment evaluates the relationship between the number of components migration in and the number of devices. This relationship can reflect the equilibrium level of migration in the many-to-many component migration.Fig.2 shows the many-to-many component migrate-on, if δ=0 ,so, the number of the component migration in devices are not balanced distribution, but, as the value of δ increases, δ=10 ,Fig.3 shows the number of migration component and devices reaches to equ-ilibrium.

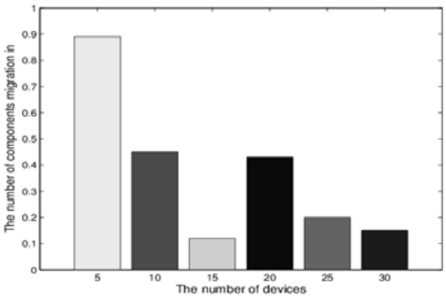

Fig.2. Many-to-many component migration, δ=0

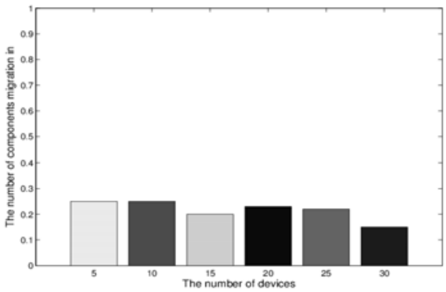

Fig.3. Many-to-many component migration, δ=10

(2) The ratio of number of components migration in(MIC) and migration out(MOC): ϕ =MIC/MOC, ϕ , δ are used to reflect whether the components maintenance can be completed within the deadline time, it is shown in Fig.4. As the value of δ increases, the more the ϕ value ,more longer component of the migrati-on time, which results in increased possibility of maintenance failure within the deadline time. This beca-use of the more ϕ value ,the more components migration in devices, which makes the device become very crowded,component migration slows down.The value of ϕ increasing makes the components have to ch-oose new device to migrate, which increases its path length of reaching the failure source device,therefore, the component migration time is too long and more than deadline, maintenance will become invalid.

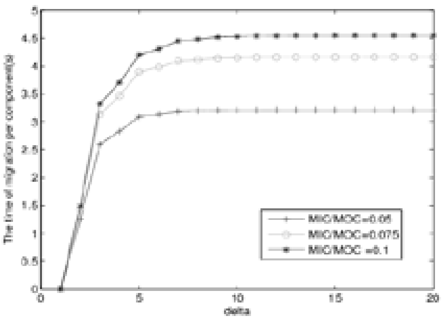

Fig.4. Effect of value of δ and ϕ on each component migration time

4. Conclusion

This paper has presented a component-based migration service maintenance strategy, which is a way to find related matching component and replace a failed component. A CM-ECA maintenance framework proposed according to analysis of the process of component maintenance from the three levels. In particular, the process of the migration path selection needs large network overhead in order that service component can migrate to failure source device side in the deadline time, otherwise, the migration becomes invalid. However, component-based migration approach is no needs additional external services composition device because it is to migrate component and directly replace failed components,which not only reduces utilization of the IOT network resources, but also do not need to check from one-hop to multiple-hop link. The results show that the maintenance strategy effectively balances the load migration and makes the matching components to be migrated and failed components to be replaced within the deadline time.

Acknowledgements

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